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FROZEN CONCENTRATED APPLE JUICE

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Page 2399: The sentence beginning on next to last line, 1st column and the succeeding sentence should be replaced by:

"The cloths should be coated with about 6 pounds of filter aid for each 100 sq. ft. of filter surface and approximately 5 pounds of filter aid should be added to each 100 gallons of juice. Dicalite Special Speedflow or equivalent can be used."

Page 2401, Table III, Item 8: Change to read as follows:

"Filter Presses: Two required; plate-and-frame stainless steel; operates 4 hours per press without redressing; each press 18" x 18" with 17 two-inch frames. $9,000 "

Note: This change raises the equipment cost by $5,700, but makes no significant difference in the cost to make the product.

Page 2401, Table III: Insert item 11A, viz:

"Item 11a cooler: Stainless steel throughout; fixed tube sheets and removable heads; cools 0.7 gpm from 210° F. to 100° F.; 7 sq. ft.; 9 tubes 4 ft. long; 3/4 inches O.D., 18 ga. $200 "

Page 2402, Table IV, Item 8: Should read as follows:

"Filter Presses: Plate and frame, stainless steel. Two presses required, operates 4 hours per press before cleaning. Each press 30" x 30" with 23 two-inch frames. $14,400 "

Note: This increases the total equipment cost by $8,300 but makes no significant difference in the cost to make the product.

Page 2402, Table IV: Insert Item 11A, viz:

"Item 11a cooler: Stainless steel throughout; fixed tube sheets and removable heads; cools 2.5 gpm from 210° F. to 100° F.; 24 sq. ft.; 20 tubes 6 ft. long; 3/4 inches O.D., 18 ga. $600 "

Frozen Concentrated Apple Juice

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The work was done to increase the consumption of juice grade apples by developing a new juice product having the flavor of freshly pressed apple juice.

It was found that such a product could be made by stripping the aroma from the fresh juice, concentrating the aroma to an essence by a process previously developed at this laboratory, then concentrating the stripped juice about fourfold under vacuum, reincorporating the essence, canning, and freezing. On adding 3 volumes of water to one of frozen concentrate the consumer can obtain a beverage with the aroma and taste of freshly pressed juice. In this regard the new product is superior to most of the single-strength bottled apple juice on the market. The cost of making and distributing the new product is less (on an equivalent juice basis) than for single-strength juice.

The principles of volatile flavor recovery can be applied to the manufacture of frozen concentrated fruit juices. Where, as in the case of apple, the juices can be concentrated under a moderate vacuum without heat damage, the product should be capable of manufacture and distribution at less cost than a single-strength juice. The superior quality of the resulting beverage and the convenience of handling a concentrate in the home should increase the consumption of apple juice.

THE rapid development of the frozen concentrated orange juice industry has stimulated wide interest in the production of other frozen juice concentrates. This laboratory has published the results of some work on frozen concentrated Concord grape juice (*3*) and the Western Regional Research Laboratory has reported on frozen concentrates from the depectinized, clarified juice of apples grown in the Pacific Northwest (*5, 8*). Work at the Eastern Regional Research Laboratory on frozen concentrated apple juice has dealt with a product made from eastern grown varieties. As there is a preference in eastern markets for apple juice that has not been clarified, the product described here contains the pectin originally present in the juice as well as the slight cloudiness that characterizes a juice from which the pectin has not been removed. This publication gives tentative recommendations and cost estimates that should be of timely interest to potential manufacturers of such a product.

GENERAL PROCESS

A flow sheet of the process is shown in Figure 1.

It consists of taking the juice, extracted in the conventional way from sound apples, straining it through a 200-mesh screen, and then pumping it to an essence recovery apparatus to obtain the aroma in concentrated or "essence" form. The stripped juice is then filtered and concentrated under vacuum to approximately 45° Brix, the essence is added to the cooled concentrate, and the mixture is packed in 6-ounce cans and then frozen and stored at −10° F. When reconstituted with 3 volumes of cold water per volume of concentrate, the product will have the aroma and flavor of freshly pressed apple juice.

This process is recommended in preference to the well-known "Florida process" used with citrus juices, in which the juice is concentrated under high vacuum to 50° to 65° Brix and fresh "cut-back" juice is then added to give a concentrate of 42° Brix containing pulp. The choice was dictated by the following factors:

Apple juice does not require the expensive very high vacuum equipment necessary to avoid flavor damage to orange juice.

Most apple juices cannot be concentrated beyond 55° unless first depectinized, and for the eastern market a nondepectinized juice is preferred.

The techniques of recovering the aroma of apple juice in essence form are well established, whereas they have not been perfected for citrus juices.

The use of essence should restore the full quota of aroma to the product, in contrast to only partial restoration by the cut-back juice in the Florida process.

Tests comparing the initial quality of products made by the recommended process and the Florida process, both diluted to 10.5° Brix for testing, showed the former to be superior. In applying the Florida process the juice was not depectinized, and was concentrated to 50° Brix under a vacuum of 28.6 inches of mercury, which is not as high a vacuum as that employed with orange juice. However, in making the product containing essence, juice was concentrated under the same vacuum. The factor of temperature during evaporation, as affecting flavor damage, was therefore the same in both cases. A trained taste panel could in neither case detect any heat damage, but reported a significant superiority in the product made with essence instead of cut-back juice.

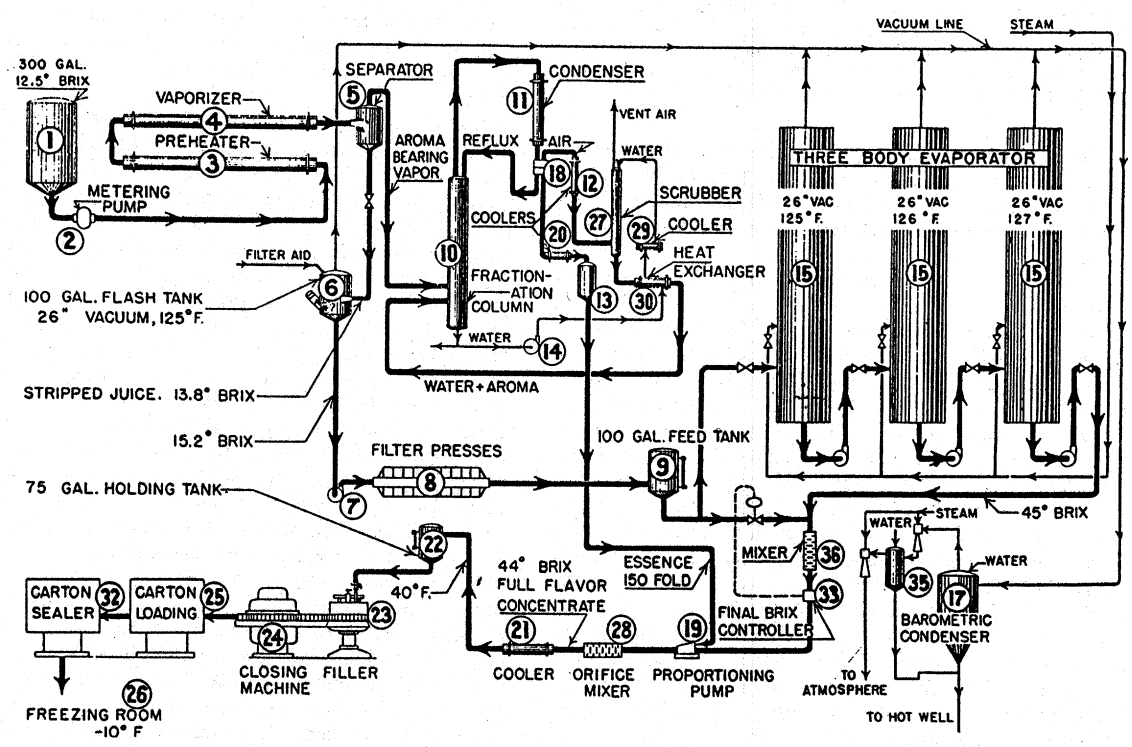

Figure 1. Flow Sheet of Process for Making Frozen Concentrated Apple Juice

417 gallons per hour of juice. 2203 6-ounce cans per hour. 44° Brix full-flavor concentrate

DETAILS OF OPERATIONS

On a basis of comparable cost and quality with single-strength juice, frozen concentrated apple juice should find a market because of its convenient package form. However, if the fullest market potentialities are to be realized, advantage should be taken of the fact that its quality can be made to surpass many of the single-strength juices now on the market. To achieve that superiority the frozen product should be made under sanitary conditions comparable to those used in making frozen concentrated orange juice. It must be made from the properly blended juice of sound apples of the right maturity, processed so as not to injure the flavor. For this reason reference is made here to what are generally considered to be sound practices in juice preparation. These, unlike the recommendations for making the frozen concentrated product, are not based on research conducted at this laboratory.

APPLES. Because in general a good concentrate cannot be made from a poor juice, it is important that good housekeeping and sanitation be employed and sound apples be used. It is poor economy to compromise with quality of the fruit. If juice grade apples are used, they must be carefully sorted to remove rots. Sorting conveyors should be of the roller type to expose all surfaces to view. Hand trimming of bruised areas is of questionable economy and jeopardizes quality. If done, an area of sound fruit would have to be included in the cutout and all bits of decayed material washed off.

Maturity is an important factor in flavor, as unripe fruit may contribute excessive tartness or astringency and dessert ripe apples or those held too long in storage may yield an insipid earthy juice of dark color. The optimum maturity for best flavor lies between "market ripe" and "dessert ripe" and has been appropriately termed "cider ripe" (*2*).

Apple varieties must be considered in achieving a proper balance among tartness, astringency, and aroma of the product. It is impractical to recommend an ideal blend, for each variety changes in character with season and locality. Furthermore, the processor must operate with the varieties available. In general, the blend should include enough acid varieties, typified by Northern Spy, Jonathan, or Baldwin, so the product will have an acidity of between 0.35 and 0.50% as malic acid for a juice of 12.5° Brix—i.e., the ratio of Brix to acid should preferably be between 36 and 25. (These limits were chosen by extensive taste panel tests at the Eastern Regional Research Laboratory with nine varieties of apples.) There should also be in the blend enough of the more aromatic varieties, such as McIntosh, Winesap, Jonathan, and Golden Delicious, to contribute bouquet. During the fall of 1950 an experimental pack of frozen concentrated apple juice of good quality was made at this laboratory from a blend in equal proportions of eastern grown McIntosh, Jonathan, Red Delicious, Stayman Winesap, and Baldwin apples.

The fruit should be thoroughly washed to remove dirt and spray residues. Experience has shown that a first wash containing 0.5% of hydrochloric acid and a detergent such as Emulphor ELA followed by a water rinse is satisfactory.

JUICE PREPARATION. The sorted washed apples are ground in a hammer mill having a screen with holes 0.5 inch in diameter.

They are then pressed in a rack and frame press in the usual way.

Dry press cloths should be soaked overnight before use. Cloths should be washed at least every 4 hours to remove adhering pomace, then steamed to destroy microorganisms and finally rinsed. Nylon cloths are finding increasing use. Racks and frames and all parts of the press coming in contact with the juice should be washed, on the same schedule as the cloths, with high pressure hot water jets. The racks should be steamed and, after partial drying to prevent souring, they may be stacked in a way to permit air circulation.

The juice from the press is screened through a reel covered with 200-mesh stainless steel screen to remove tissue fragments. It is then pumped to a holding tank, from which it is fed at a fixed rate to the essence recovery unit. There should be a minimum of delay between pressing and essence stripping. Permitting the juice to stand may result in loss of aroma or in fermentation to a degree where the essence may contain alcohol above the legal limit (*4*).

Essence Recovery. The purpose of recovering the aroma in essence form is to enable restoring to the concentrate the fragrance of the fresh apples without significant dilution. This fragrance would otherwise be lost during vacuum concentration of the juice.

The basic design for an essence recovery unit with a capacity of 1000 gallons an hour of juice was published by Milleville and Eskew (*6*). More recently improvements in essence recovery equipment, especially as regards time of heating the juice, have been developed. A pilot plant unit embodying these improvements has been described (*7*). Tables III and IV contain the basic engineering data for the design of essence recovery units having a capacity of 417 and 1500 gallons per hour, respectively, of juice when vaporizing 10% as is customary with apples. The improvements over earlier designs include separation of the evaporator into preheating and vaporizing sections, thereby minimizing surging and reducing the time at which the juice is held above 210° F. from about 20 seconds to less than 3 seconds. This is done by making the diameter of the preheater tube small, so as to give a high juice velocity, preferably 9 to 15 feet per second, and by careful design of all piping and parts carrying hot juice, so as to reduce their volume to a minimum. Furthermore, the preheater tube is chosen small enough to attain turbulent flow, by the Reynolds number criterion, in the preheater. Besides ensuring uniform heating of all parts of the stream of juice passing through the preheater, this reduces fouling of the tubes. This system of essence stripping does not damage the flavor of the juice. It pasteurizes it and inactivates any enzymes that may be present.

Brown *et al.* (*1*) have used a device which heats the juice by direct injection of steam instead of by passing it through a steam-heated tube, to reduce heating time and to eliminate fouling of tubes. This device requires a special supply of odorless steam, and necessitates re-evaporating out of the juice the water resulting from the condensation of the injected steam, which will amount to about 13% of the weight of the juice.

The vent gases from the condenser are scrubbed with chilled column bottoms instead of with chilled essence as formerly.

Clarification. The juice is not clarified to the brilliance that results from depectinization followed by filtration. In some markets, especially in the eastern United States, such a product is less popular than a slightly cloudy one, for it deviates too much from the popular idea of how apple juice should look and some of the body is lost through pectin removal. The clarification recommended here is achieved by the very rapid heating incident to essence recovery and the subsequent filtration of the stripped juice through cotton twill cloths using filter aid. The heating causes colloidal materials to coagulate and give an easily filterable juice and a product which, although not brilliant, is only very slightly cloudy. Stainless steel plate and frame filter presses may be used. The cloths need not be precoated with filter aid. One pound of a filter aid such as Dicalite Speedflow is thoroughly mixed with each 100 gallons of juice in the flashed juice receiving tank. When a freshly dressed press is started up, the juice is recycled from the press to the feed tank until it flows clear. Thereafter it is discharged to the filtered juice feed tank from which the evaporator is fed.

The stripped juice as it leaves the essence recovery equipment is effectively pasteurized; biological tests show complete destruction of yeasts and of all bacteria capable of surviving in the juice. Experiments in which conventional pasteurization—i.e., 3 minutes at 180° F.—was superimposed on the foregoing heat treatment incident to essence recovery, showed this additional pasteurization to be not only superfluous but detrimental. The product from stripped juice which had been given the additional pasteurization treatment had a slight but perceptible cooked flavor.

Concentration of Stripped Juice. Assuming that the essence to be used in the concentrate is 150-fold, the stripped juice will have to be concentrated to 45° Brix, so that on addition of the essence the product can be diluted with 3 volumes of water to yield a 12.5° Brix beverage. This must be done under such time-temperature conditions as not to damage the flavor. The very high vacuum—e.g., 29.5 inches of mercury—necessary with heat-sensitive orange juice is not required for apple juice. Last season the authors prepared a frozen concentrate which has thus far maintained its initial high quality for one year's storage at 0° F. The juice had been concentrated at a 27-inch vacuum. This season the frozen concentrate was made from a blend in equal proportions of freshly harvested eastern grown McIntosh, Jonathan, Red Delicious, Stayman Winesap, and Baldwin apples. In order to determine the effect of vacuum on juice concentration, the juice was evaporated to 45° Brix in a single effect evaporator at vacua of 26.0, 27.5, and 28.5 inches of mercury, taking 80 minutes to boil down the batch, using steam at atmospheric pressure. The average boiling points of these batches during concentration were 120°, 104°, and 85° F., respectively. Full-flavor frozen concentrates of 44° Brix were made by adding essence and were submitted to a trained taste panel. The panel could detect no difference in the character of the products made from juices concentrated under the different vacua. None of them had any cooked taste or aroma; all were of excellent quality and superior to the starting juice in that they had no earthy character. It is probable that this earthy flavor was eliminated by the clarification used in making the finished product. These products have now been stored 9 months at 0° F. without any signs of deterioration. It has also been shown (*8*) that a concentrate can be prepared in a falling film evaporator from the depectinized clarified juice of a 20:80 blend of western grown Delicious and Winesap apples without initial heat damage at normal temperatures up to 130° F. (25.5-inch vacuum).

In the light of the foregoing facts there seems little doubt that the product described herein can be safely concentrated under a 26-inch vacuum. Typical units for accomplishing this correspond to item 15 in Tables III and IV.

Incorporation of Essence. A proportioning pump, followed by an orifice mixer, continuously mixes 2.75 gallons of 150-fold essence with each 100 gallons of 45° Brix concentrate to yield a concentrate of 44° Brix containing all the aroma of the freshly made juice. A single motor operates the entire proportioning pump, with automatic cutoff in event of failure of one of the streams coming to the pump.

To ensure a concentrate stream of constant Brix (or constant density) coming to the proportioning pump, the discharge from the evaporator is roughly maintained at a concentration somewhat higher than 45° Brix. The final adjustment to 45° Brix is made by continuously blending small amounts of the pasteurized evaporator feed with the evaporator discharge, the mixing valve being operated by an automatic density controller. The addition of small quantities of evaporator feed juice at this point is done only to simplify the operation of the evaporator and is not analogous to the practice of the Florida process of adding large quantities of fresh cut-back juice to replace some of the aroma and flavor lost in the evaporators. There is no need for adding any fresh juice to enhance the aroma, as it is recovered in the essence.

FILLING AND PACKAGING. There are in general two methods of freezing and packaging juice concentrates. In one the juice is filled cold in the cans and the cans are then packaged and loaded into a freezing room; in the other the juice is either slush frozen and canned or the cans are liquid-filled and the contents are quick frozen before further packaging. For illustrative purposes the authors have chosen the former, as the equipment is less complicated and in that respect is better suited to a plant of moderate size.

The concentrate is chilled to 40° F. by a brine cooler before filling. It has a viscosity of approximately 270 centipoises at this temperature, necessitating the use of a piston-type can-filling machine. As the temperature of the contents of the cans determines the freezing time and therefore the size of the freeze room required, the filling temperature was chosen as low as practicable to reduce the load on the freeze room and still allow the material to be satisfactorily handled by the filling machine.

The cans are carried by ordinary belt conveyors to a standard can-closing machine. The belt conveyor from the closing machine is attended by two women loading the cans by hand, 24 to a carton. The same conveyor carries the cartons to an automatic sealing machine. The sealed cartons are loaded by hand onto pallets—e.g., 34 inch × 41 inch pallets, 84 to a pallet—and the pallets are brought to the freeze room by a forked lift truck. One man is needed for pallet loading and trucking.

The freeze room holds 3 days' production. With adequate air blast within the room, 24 to 30 hours should be sufficient to freeze the cans. The room operates at −10° F. and requires 12 tons of refrigeration.

COSTS

In estimating the cost of manufacturing frozen concentrated apple juice (as of January 1951), it is assumed that the operations will be carried out by a company already in the business of producing single-strength juice. The estimates therefore cover only the cost subsequent to juice manufacture. It is further assumed that a suitably fenced plot, roads, parking areas, railroad sidings, trucking facilities, and office furniture and fixtures are already available. However, an allowance is made for the additional buildings, including a boiler house, and for the preparation of the building site.

As it is unlikely that a small producer of apple juice would be in a position to make the large investment for conversion to the frozen concentrated product, the primary cost estimates are based on a plant processing 417 gallons of juice per hour, equivalent to approximately 2.7 tons of apples. The factory would turn out 2203 6-ounce cans of frozen concentrated apple juice per hour. This assumes that the starting juice is 12.5° Brix and is available at a rate of 417 gallons per hour. The finished product will be 44° Brix, and will yield a juice of 12.5° Brix when diluted with 3 volumes of water. The factory is assumed to operate 75 days per year, 5 days per week, 16 hours per day—i.e., two 8-hour shifts plus additional time for cleanup operations. Costs are also given for another plant operating on the same cycle, but having a capacity of 1500 gallons of juice per hour.

Capital costs are shown in Table I. It will be seen that the total fixed capital required is $206,600 for a plant processing 417 gallons per hour of juice into frozen concentrate, and $30,000 working capital is required. By a rough approximation of the fixed capital for plants of other capacities, the cost may be assumed to be proportional to the 0.6 power of the capacity (*9*). For example, the fixed capital required for a plant with a capacity of 800 gallons of juice per hour would be $\$206,200 \times \frac{(800)^{0.6}}{(417)}$, which is $305,000. To show the effect, on production costs as well as on capital costs, of a great increase in the size of plant, al-

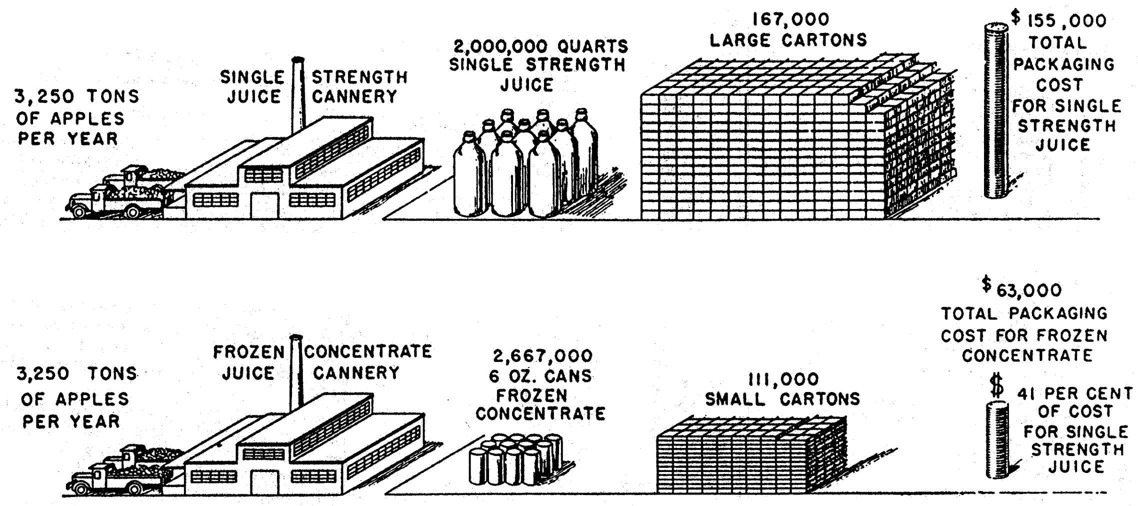

Figure 2. Comparative Packaging Cost of Concentrate and Single-Strength Juice
417 gallons per hour

TABLE I. CAPITAL COSTS

	417 Gal./Hour	1500 Gal./Hour
Site preparation	$ 2,000	$ 4,500
Building	22,000	47,000
Boilers	11,000	35,000
Equipment	56,000	127,000
Erection of equipment	14,000	32,000
Instrumentation	1,500	3,200
Piping and ductwork	23,000	57,000
Erection of piping and ductwork	16,000	40,000
Heating, installed	2,000	5,000
Lighting, installed	2,000	4,500
Power, installed	4,000	9,000
Freight on equipment	1,100	2,500
Contingencies	21,000	49,000
Engineering fees	31,000	73,000
Total fixed capital	$206,600	$488,700
Working capital	30,000	73,000
Total capital	$236,600	$561,700

Table II. Cost Sheet

(75 days' operation, 16 hours per day)

	Juice, Gal. per Hour 417	1500
	Cans per Hour 2203	7919
	Cost per Day, Dollars	
1. Material	$ 1.32	$ 4.70
Filter aid	1.32	4.70
Total material cost	233.60	249.64
2. Labor	$ 234.92	$ 254.34
3. Prime cost		
4. Indirect materials	$ 0.22	$ 0.48
Filter cloth	704.86	2534.12
Cans	98.36	353.06
Cartons	0.33	0.75
$CaCl_2$	$ 803.77	$2888.41
Total		
5. Factory overhead		
6. Indirect labor	$ 48.00	$ 80.00
a. Supervision	41.07	41.07
b. Watchmen, yardmen	16.00	16.00
c. Mechanics, etc.	8.00	15.00
d. Office help	8.00	15.00
e. Truck operator		
7 Indirect expenses	13.77	32.47
a. Insurance, public liability and fire	55.09	129.89
b. Taxes	137.73	324.74
c. Interest, fixed capital	5.33	6.40
d. Social Security	3.91	4.28
e. Workmen's compensation	10.40	11.97
f. Unemployment insurance	275.47	649.47
g. Depreciation	131.67	310.46
h. Maintenance, repairs, and renewals	19.48	45.95
i. Power	33.82	125.12
j. Steam	10.07	35.03
k. Water	3.65	5.50
l. Gasoline	3.73	8.43
m. Factory supplies	$ 825.19	$1856.78
8. Total factory overhead	$1863.88	$4999.53
9. Factory cost	5.48	13.35
10. Interest on working capital	52.12	97.28
11. Administrative and general expense	$1921.48	$5110.16
12. Cost to make	35,248	126,704
13. Cans made per day	$0.0545	$0.0403
14. Cost per can		

ternative cost estimates have been made for a plant of 1500-gallon-per-hour capacity. The total fixed capital required is $488,700 and the working capital is $73,000. The make-up of the capital cost figure is shown in Table I for this plant as well as for the smaller one.

Table II is a cost sheet, from which it is seen that a frozen concentrated apple juice can be produced for approximately 5.5 cents per 6-ounce can in a 417-gallon-per-hour plant, or 4.0 cents in a 1500-gallon-per-hour plant. This is the "cost to make" and includes not only the actual production and packaging costs but administration, general expense, interest on investment, and working capital. It does not include any transportation, distribution, or selling costs, nor the cost of the juice.

The costs of packaging and of transportation of frozen concentrates in 6-ounce cans are both far less than those of an equivalent amount of single-strength juice in the customary quart bottles. Quart bottles and their cartons cost about 7.70 cents per bottle; as a 6-ounce can makes 0.75 quart of juice, this is equivalent to 5.77 cents per 6-ounce can of concentrate. Six-ounce cans and their cartons cost about 2.34 cents per can, a saving of 3.43 cents per can. A quart bottle of juice weighs about 3.30 pounds, which is 2.47 pounds for the juice equivalent of a 6-ounce can of concentrate. A 6-ounce can of concentrate weighs only 0.52 pound. Freight rates, of course, vary greatly, but may usually be taken as 1.5 times as much for frozen cans as for single-strength bottled juice. On this basis, the freight cost for frozen concentrate will average only 31% as much for concentrate as for an equivalent amount of bottled juice. On a typical 200- to 250-mile haul, this is a saving of 1.00 cent per can, which, added to the 3.43-cent saving in cost of containers, totals 4.4 cents per can. In the typical 417-gallon-per-hour plant, these savings would provide funds for more than 80% of the total "cost to make," which, as defined above, includes all costs and fixed charges except the cost of the raw juice. In a 1500-gallon-per-hour plant the saving of 4.4 cents per can would more than pay for the entire cost to make. Actually, the financial picture is even more favorable than this, because no credit has been taken, in this calculation, for omitting the costs of the pasteurizing and bottling operations, which are a part of the production of conventional bottled juice. This credit has been omitted so as to cover the immediate amortization of the bottled juice processing equipment by any processor who already has it. Moreover, it is to be expected that the high quality and fresh character of the concentrate and its greater convenience in the household would give it a greater consumer appeal than single-strength pasteurized juice, and should secure a higher selling price.

The annual saving in cost of containers by making frozen concentrate instead of bottled juice is depicted in Figure 2. It

Table III. Equipment List for Plant Producing 417 Gallons per Hour

(See Figure 1 for corresponding numbers)

Item No.	Equipment	Cost
1	Holding Tank. 300-gal. capacity, stainless steel, dished bottom, removable top with hand hole for filling, bottom discharge	$ 1,000
2	Pump. Positive delivery sanitary type, stainless steel, 417 gal./hour at 50 lb./sq. inch	300
3	Preheater. Stainless steel except carbon steel shell. Tubes 3/8 inch o.d., 18-gage (0.275 i.d.) tubes 18 feet long. 2 passes, 4 tubes per pass. 14 sq. feet outside tube surface	1,500
4	Vaporizer. Stainless steel, except carbon steel shell. Single pass. 5 tubes, 1 inch o.d., 18 gage, 20 feet long. 25 sq. feet outside tube area	1,500
5	Liquid-Vapor Separator. Stainless steel. Diameter of separator body 8 inches, vapor outlet 4 inches diameter, vapor inlet 3 inches diameter, over-all height 8 inches	300
6	Flash Cooling Tank. Stainless steel closed tank, standard dished heads, 100-gal. capacity. Side agitator. Hand holes and feeder for filter aid. Operates at evaporator vacuum	1,300
7	Pump, Centrifugal. Stainless steel, sanitary type, 400 gal./hour, 80-foot head	200
8	Filter Presses. Plate and frame, stainless steel. Two presses required, operate 8 hours per press, before cleaning and dumping. Each press 12 × 12 inches with 8 2-inch frames	3,300 (for 2)
9	Holding Tank. Stainless steel, 100-gal. capacity	400
10	Fractionating Column. Packed tower with stainless steel shell, packing supports, reboiler, and accessories, 9-inch diameter shell packed with 1-inch Raschig rings. Total height 9 feet—6-inch enriching section, 2-foot stripping section, 1-foot spacing section. Operates at less than 80% of flooding	1,000
11	Condenser. Stainless steel, single-pass, fixed tube sheets and removable heads. Condensate on inside of tubes. Condenses 42 gal./hour. 5 sq. feet outside tube surface	200
12	Heat Exchanger. Gas cooler. Volume of noncondensable gas assumed 10% of feed. Stainless steel, fixed tube sheets, removable heads. 4 sq. feet outside tube surface	150
13	Essence Receiver. Stainless steel with removable top head. 5-gal. holding capacity	100
14	Pump, Centrifugal. Stainless steel, sanitary type, 10 gal./hour at 20-foot head	100
15	Evaporator. Three-body outside calandria type. All parts in contact with product made of stainless steel. Consists of 3 units all operated at a pressure of 4 inches Hg absolute, juice flowing continuously through 3 in series. Steam supplied to calandria at 10 lb./sq. inch gage. Evaporation 1900 pounds per hour. Price of evaporator complete includes structural supports, circulation pumps and piping, vapor pipe, condenser, tail pipe, vent piping, calandrias, condensate piping, liquor	10,000

(*Continued on page 2402*)

Table III. Equipment List for Plant Producing 417 Gallons per Hour (*Concluded*)

(See Figure 1 for corresponding numbers)

Item No.	Equipment	Cost
	piping, discharge pumps, vapor relief valves, air ejectors, pressure reducing valve, hogging jet for evacuating when starting up, and condensate pump	
17	Barometric Condenser. Of sufficient size to handle vapor from evaporator and flashed vapor from flash cooling tank (item 6). Condenser provided with tail pipe 34 feet long discharging into hot well and two-stage ejector with intercondenser for removal of noncondensable vapors. Price included in item 15	
18	Liquid Noncondensable Separator. Sight glass with stainless steel accessories. Price included in item 20	
19	Pump, Proportioning. Stainless steel. Mixes in proportion of 100 gal. of 45° Brix concentrate and 2.75 gal. of 150-fold essence	$ 1,400
20	Cooler. Stainless steel, except carbon steel shell. Single-pass, fixed tube sheets, removable heads, 1.25 sq. feet outside tube surface. Price includes item 18	100
21	Brine Cooler. Stainless steel, except carbon steel shell. Single-pass, fixed tube sheets, removable heads. Product inside tubes, brine outside. 7-sq.-foot outside tube surface. Cooler insulated with 4-inch cork	200
22	Holding Tank. Stainless steel closed tank with breather, standard dished heads. Top head removable. 80-gal. capacity, insulated with 3-inch cork insulation	400
23	Filling Machine. Fills 37 6-ounce cans per minute. Piston type. Fill to within 0.5% accuracy	2,500
24	Closing Machine. Closes 37 6-ounce cans per minute, standard closing machine	1,700
25	Conveyors. From and to closing machine, ordinary belt conveyors	500
26	Freeze Room. Operates at −10° F. Must hold 2 days' freeze plus 1 day's storage = 3 days in freeze room 35,243 × 3 = 105,729 cans to be provided for, 2016 cans per pallet. 105,729/2,016 = 55 pallets. Pallets 34 × 41 inches. Make room 20 × 35 feet = 700 sq. feet. Room insulated with 8-inch cork. Refrigeration required, 12 tons	15,000
27	Scrubber. Volume of condensable gas 10% of feed by volume. Stainless steel. Scrubber 2 inches diameter by 5 inches long, packed with 1/4-inch saddles	100
28	Orifice Mixer. Series of 6 offset orifices in pipe serves as mixer	100
29	Liquid Cooler. Stainless steel. Fixed tube sheets, removable heads, brine inside tubes, product outside tubes. 1.48 sq. feet outside tube surface	100
30	Heat Exchanger. Stainless steel. Fixed tube sheets, removable heads, single pass. 3.4 sq. feet outside tube surface	150
32	Carton Sealer. Closes cartons when cans have been loaded in cartons	200
33	Brix Controller. Controls discharged product from evaporators. Holds concentrate at 45° Brix for blending. Automatic device for control of blending operations to secure constant specific gravity (Brix)	1,200
35	Jet Vacuum Pump. Two-stage, with intercondenser. Cost included in item 17	
	Brine System. Heavily insulated brine tank, two centrifugal pumps and piping	1,000
	Pallets. 34 × 41 inches. 2016 cans per pallet, 100 pallets at $4.75	500
	Trucks, Hand Lift. 4 required at $375 each	1,500
	Refrigeration. Additional for brine system. 4.5 tons	4,000
	Condensing Water Supply. Centrifugal pump, 200 gal./min. Pipeline, 4-inch; accessories	3,000
		$56,000

Note. Items 16, 31, and 34 deleted.

Table IV. Equipment List for Plant Producing 1500 Gallons per Hour

(See Figure 1 for corresponding numbers)

Item No.	Equipment	Cost
1	Holding Tank. 1000-gal. capacity, stainless steel, dished bottom, removable top with hand hole for filling. Bottom discharge	$ 2,300
2	Pump. Positive delivery sanitary type, stainless steel, 1500 gal./hour at 50 lb./sq. inch	700
3	Preheater. Stainless steel, except carbon steel shell. Tubes 3/8-inch o.d., 18-gage (0.275 i.d.) tubes 12 feet long. 3 passes, 14 tubes per pass. 48.4 sq. feet outside tube surface	2,200
4	Vaporizer. Stainless steel, except carbon steel shell. Single pass. 18 tubes, 1 inch o.d., 18 gage. 20 feet long. 94.24 sq. feet outside tube area	2,400
5	Liquid-Vapor Separator. Stainless steel. Diameter of separator body 14 inches, vapor outlet 6-inch diameter, length inside 23 inches, vapor inlet 5 inches diameter, overall height 42 inches	600
6	Flash Cooling Tank. Stainless steel closed tank, standard dished heads, 300-gal. capacity. Side agitator. Hand holes and feeder for filter aid. Operates at evaporator vacuum	2,100
7	Pump, Centrifugal. Stainless steel, sanitary type, 22.5 gal./min. at 80-foot head	250
8	Filter Presses. Plate and frame, stainless steel. Two presses required, operates 8 hours per press before cleaning and dumping. Each press 24 inches × 24 inches with 8 2-inch frames	6,100 (for 2)
9	Holding Tank. Stainless steel, 300-gal. capacity	700
10	Fractionating Column. Packed tower with stainless steel shell, packing supports, reboiler and accessories, 14-inch diameter shell packed with 1.25-inch Raschig rings. Total height 13 feet—10-foot enriching section, 2-foot stripping section, 1-foot spacing section. Operates at less than 80% of flooding	2,000
11	Condenser. Stainless steel. Single-pass, fixed tube sheets and removable heads. Condensate on inside of tubes. Condenses 150 gal., 1242 lb./hour. 18.1 sq. feet outside tube surface	400
12	Heat Exchanger. Gas cooler. Volume of noncondensable gas assumed 10% of feed. Stainless steel, fixed tube sheets, removable heads. 14 sq. feet outside tube surface	300
13	Essence Receiver. Stainless steel with removable top head, 15-gal. holding capacity	150
14	Pump, Centrifugal. Stainless steel, sanitary type, 10 gal./hour at 20-foot head	150
15	Evaporator. Three-body outside calandria type. All parts in contact with product made of stainless steel. Consists of 3 units all operated at pressure of 4 inches Hg absolute, juice flowing continuously through 3 in series. Steam supplied to calandrias at 10 lb./sq. inch gage. Evaporation 7173 lb./hour. Price of evaporator complete includes structural supports, circulation pumps and piping, vapor pipe, condenser, tail pipe, vent piping, calandrias, condensate piping, liquor piping, discharge pumps, vapor relief valves, air ejector pressure reducing valve, hogging jet for evacuating when starting up and condensate pump	22,900
17	Barometric Condenser. Of sufficient size to handle vapor from evaporator and flashed vapor from flash cooling tank (item 6). Condenser provided with tail pipe 34 feet long discharging into hot well, and two-stage ejector with intercondenser for removal of noncondensable vapors. Price included in item 15	
18	Liquid Noncondensable Separator. Sight glass with stainless steel accessories	100

Table IV. Equipment List for Plant Producing 1500 Gallons per Hour (*Concluded*)

(See Figure 1 for corresponding numbers)

Item No.	Equipment	Cost
19	Pump, Proportioning. Stainless steel. Mixes in proportion of 100 gal. of 45° Brix concentrate and 2.75 gal. of 150-fold essence	$3,300
20	Cooler. Stainless steel, except carbon steel shell. Single pass, fixed tube sheets, removable heads, 1.25 sq. feet outside tube surface	100
21	Brine Cooler. Stainless steel tubes, except carbon steel shell. Single-pass, fixed tube sheets, removable heads. Product inside tubes, brine outside. 20.2 sq. feet outside tube surface. Cooler insulated with 4-inch cork	400
22	Holding Tank. Stainless steel closed tank with breather, standard dished heads. Top head removable. 200-gal. capacity and insulated with 3-inch cork insulation	1,000
23	Filling Machine. Fills 132 6-ounce cans per minute. Piston type. Fills to within 0.5% accuracy	4,600
24	Closing Machine. Closes 132 6-ounce cans per minute, standard closing machine	3,000 (rental)
25	Conveyors. From and to closing machine, ordinary belt conveyors	800
26	Freeze Room. Operates at −10° F. Must hold 2 days' freeze plus 1 day's storage = 3 days in freeze room 126,711 × 3 = 380,133 cans to be provided for, 2016 cans per pallet. 380,133/2,016 = 190 pallets. Pallets 34 × 41 inches. Make room 40 feet × 55 feet = 2,200 sq. feet. Room insulated with 8 inch cork. Refrigeration required, 40 tons	41,000
27	Scrubber. Volume of condensable gas is 10% of feed by volume. Stainless steel. Scrubber 2 inches in diameter, 5 feet long, packed with 1/4-inch saddles	100
28	Orifice Mixer. Series of 6 offset orifices in pipe serves as mixer	100
29	Liquid Cooler. Stainless steel. Fixed tube sheets, removable heads, brine inside tubes, product outside tubes. 1.48 sq. feet outside tube surface	100
30	Heat Exchanger. Stainless steel. Fixed tube sheets, removable heads, single pass. 3.4 sq. feet outside tube surface	150
32	Carton Sealer. Closes cartons when cans have been loaded in cartons	200
33	Brix Controller. Controls discharged product from evaporators. Holds concentrate at 45° Brix for blending. Automatic device for control of blending operations to secure constant specific gravity (Brix)	1,400
35	Jet Vacuum Pump. Two-stage, with intercondenser. Cost included in item 17	
	Brine System. Heavily insulated brine tank, two centrifugal pumps and piping	5,000
	Pallets. 34 × 41 inches. 2016 cans per pallet, 350 pallets at $4.75	1,700
	Trucks, Hand Lift. 6 required at $378 each	2,400
	Refrigeration. Additional for brine system. 15.5 tons	11,200
	Condensing Water Supply. Centrifugal pump, 600 gal./min.; pipeline, 6 inches; accessories	6,500
		$127,000

Note. Items 16, 31, and 34 deleted.

amounts to $92,000 per year for a plant processing 417 gallons of juice. The great reduction in space occupied in warehouses is graphically shown.

Table III gives brief descriptions of the major pieces of equipment and the estimated cost of each, for the 417-gallon-per-hour plant; Table IV gives similar data for the 1500-gallon plant. The numbers correspond to those shown in Figure 1. These particular pieces of equipment, and the sizes and descriptions thereof, are chosen merely to illustrate one way of carrying out the process, and to establish a basis for making a cost estimate. For many of the processing steps described, other apparatus of equivalent functioning can be substituted for that listed here. Moreover, choice of apparatus has been made on a liberal basis, rather than in an attempt to determine the absolute minimum costs.

SUMMARY

The rapid development of the frozen concentrated orange juice industry has stimulated wide interest in the production of other frozen juice concentrates. Unlike frozen orange juice concentrate, which contains aroma only to the extent that fresh cut-back juice is added during manufacture, a frozen concentrated apple juice can be made containing all the aroma of the freshly made juice.

The aroma is first rapidly stripped from the juice and concentrated to an essence by a process developed several years ago at the Eastern Regional Research Laboratory. The stripped juice is concentrated under a moderate vacuum to about 45° Brix. The previously recovered aroma is added, giving a full-flavor concentrate of 44° Brix which is then frozen in 6-ounce cans. This product when diluted with 3 volumes of water will give a beverage almost indistinguishable from freshly made apple juice and in that respect superior to conventional bottled pasteurized juice.

Cost estimates have shown that an apple processing plant producing 417 gallons of juice an hour could be converted to a frozen concentrate plant by a total capital investment of about $206,600. In such a plant, freshly pressed apple juice could be processed into frozen full-flavor concentrate at a total cost of 5.5 cents per 6-ounce can, including costs of containers and all overhead, but not cost of fresh juice. For a plant of the largest size, 1500 gallons per hour, the conversion cost would be $488,700 and the total processing cost 4.0 cents. The saving in cost of containers over those required for bottled juice is equivalent to 3.4 cents per can, thus repaying most or all of the total processing cost. Freight costs are also less.

LITERATURE CITED

(1) Brown, A. H., Lazar, M. E., Easserman, T., and Ramage, W. D., *Food Packer*, 32 (1), 20–1, 38, 40, 42, 44 (1951); 32 (2), 34–5, 73–4 (1951).

(2) Caldwell, J. S., U. S. Dept. Agr., *Farmers Bull.* 1264 (revised 1938).

(3) Eskew, R. K., Phillips, G. W. M., Homiller, R. P., and Eisenhardt, N. H., *Food Inds.*, 22, 1026–8 (1950).

(4) *Federal Register*, 14 (186), 5869–79 (1949).

(5) Kaufman, V. F., Nimmo, C. C., and Walker, L. H., U. S. Dept. Agr., Bur. Agr. Ind. Chem., Western Regional Research Laboratory, AIC-293 (November 1950).

(6) Milleville, H. P., and Eskew, R. K., *Western Canner and Packer*, 38, 51–4 (1946).

(7) Phillips, G. W. M., Eskew, R. K., Claffey, J. B., Davis, R. A., and Homiller, R. P., Ind. Eng. Chem., 43, 1672 (1951).

(8) Walker, L. H., Nimmo, C. C., and Patterson, D. C., *Food Technol.*, 5, 148–51 (April 1951).

(9) Williams, R., Jr., *Chem. Eng.*, 54 (12), 124–5 (1947).